Forage Yield and Fertilizer Recovery by Three Irrigated Perennial Grasses as Affected by N Fertilization[1]

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ABSTRACT

In many locations in the United States the livestock industry uses irrigated grasses for hay production. The purpose of this study, conducted in western South Dakota on heavy clay soils (Ustertic camborthids), was to determine forage yield responses and N recovery of three irrigated grasses—reed canarygrass (*Phalaris arundinacea*), garrison creeping foxtail (*Alopecurus arundinaceus*), and smooth brome (*Bromus inermis*)—to single and split N applications. Single N treatments consisted of 0, 56, 112, 224, or 448 kg N/ha applied in March. For the split N applications, these same rates were applied both in March and again after the first hay cutting. Forage yields were maximum when the grasses were fertilized with 224 kg N/ha in the split applications. Maximum forage yields ranged between 8,899 kg/ha (air-dried) for garrison creeping foxtail and 11,802 kg/ha for smooth brome. Split applications did not benefit total production at the 56 kg N/ha rate.

First cutting forage N percentages varied between 0.8 and 1.3 for N rates of 56 to 224 kg N/ha and between 1.3 and 2.3 for N rates of 224 and above. The percentage of N was highest, frequently over 3%, in second cutting forage from treatments receiving split fertilizer applications.

Percent total N recovered increased as fertilizer rate increased when all N was applied in March, but recovery was highest for the split application of 224 kg N/ha. Recovery by smooth brome forage was highest with split applications (up to 50% recovery), but was highest for the other grass species for single annual (March) applications.

Additional index words: Phalaris arundinacea, Alopecurus arundinaceus, Bromus inermis, **Split N application.**

THE heavy clay soils of western South Dakota represent many irrigated soils in the west used by the livestock industry for hay production. Heavy clay soils are common on alluvial flood plains, where irrigation water is more readily available. When used for irrigated forage production, these soils usually respond to N fertilization. However, because of their high clay content, internal drainage is often restricted, resulting in relatively low oxygen diffusion rates. Such conditions are conducive to rapid denitrification (Delwiche, 1970). Consequently, information is needed on the efficiency of utilization of N fertilizer applied to irrigated grasses on these soils.

Research on grass production from western South Dakota clay soils showed that fertilizer and supplemental water increased native forage production and its crude protein content (Cosper and Thomas, 1961). Thomas and Osenbrug (1964) found that N and P fertilization increased production from an old stand of crested wheatgrass (*Agropyron cristatum* L.) and smooth brome (*Bromus inermis* L.) Johnson and Nichols (1969), who studied 11 irrigated grasses in western South Dakota, found that the effects of N fertilization and an alfalfa (*Medicago sativa* L.) companion crop upon grass production were greater than the differences between grass species. They also found that protein percentage was increased by N or alfalfa, and that protein content was considerably greater with the alfalfa campanion crop than for either the nonfertilized or fertilized grasses.

A field experiment was conducted at Newell, S. Dak. from 1969 through 1971 to evaluate the effects of various rates and timing of N fertilization on production and protein content of three grass species under irrigation, and to determine the magnitude of N fertilizer recovery in forage from each treatment.

METHODS AND MATERIALS

Soils on the Newell Field Station, where this experiment was located, are dense clays developed from Pierre shale (Pierre-Kyle association) and have been classified as Ustertic camborthids[3]. Thomas and Osenbrug (1964) described the top 15 cm of these soils as containing 1.92% organic matter, slightly basic

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[3] USDA. 1970. Butte County, South Dakota, Soil Survey, SCS.

Table 1. Forage yield of three irrigated grasses as influenced by rate and frequency of N applied (1969–1971 average).

Annual fertilizer treatment	Reed canarygrass			Garrison creeping foxtail			Smooth brome		
	Cutting			Cutting			Cutting		
	First	Second	Total	First	Second	Total	First	Second	Total
	kg/ha								
0	1,416^{a*}	1,014^{a}	2,430^{a}	1,698^{a}	653^{a}	2,351^{a}	1,431^{a}	468^{a}	1,899^{a}
56	2,655^{a}	1,059^{a}	3,714^{ab}	3,447^{b}	681^{a}	4,128^{b}	2,734^{ab}	570^{a}	3,304^{a}
56+56†	2,733^{a}	1,454^{ab}	4,187^{b}	3,455^{b}	1,037^{ab}	4,492^{bc}	3,644^{bc}	1,332^{b}	4,976^{b}
112	4,848^{b}	1,122^{a}	5,970^{c}	5,235^{c}	765^{a}	6,000^{cd}	4,726^{cd}	859^{ab}	5,585^{b}
112+112	4,967^{b}	1,944^{bc}	6,911^{cd}	5,449^{c}	1,501^{bc}	6,950^{de}	6,042^{de}	2,197^{c}	8,239^{c}
224	6,983^{c}	1,404^{ab}	8,387^{de}	6,227^{c}	1,239^{ab}	7,466^{def}	6,643^{ef}	1,319^{b}	7,962^{c}
224+224	7,289^{c}	3,451^{d}	10,740^{g}	5,832^{c}	2,303^{d}	8,135^{ef}	7,992^{f}	3,810^{e}	11,802^{d}
448	6,840^{c}	2,046^{c}	8,886^{ef}	6,116^{c}	2,037^{cd}	8,153^{ef}	6,770^{ef}	2,818^{d}	9,588^{c}
448+448	7,465^{c}	2,972^{d}	10,437^{fg}	6,373^{c}	2,526^{d}	8,899^{f}	7,466^{ef}	3,779^{c}	11,245^{d}

* Column means with the same superscript letter are not significantly different at the 5% level. † Second application after first cutting.

with high cation exchange capacity (37 meg/100 g) and soluble P of 7.0 ppm. Average annual precipitation (1908 through 1965) at the Newell Field Station was 393 mm, of which 309 mm fell from April through September (Spuhler et al., 1968). From 1957 through 1971 annual pan evaporation averaged 1,397 mm and the frost-free season was about 131 days.

Established, uniform stands of reed canarygrass (*Phalaris arundinacea* L.), garrison creeping foxtail (*Alopecurus arundinaceus* L.), and smooth brome were used. Reed canarygrass and garrison creeping foxtail were replicated three times and smooth brome four times.

There were nine treatments, a check plot, plus eight ammonium nitrate treatments consisting of 56, 112, 224, or 448 kg N/ha applied each year in March. These same rates were applied both in March and again after the first hay cutting (late June or early July). A randomized block experiment was used with the various fertilizer rates randomized in each grass species main block. Individual plots were 2.7 × 6.1 m in size. The canarygrass and foxtail study sites were on bench-leveled, terraced fields and the brome study site was in a regularly developed field. A spreader was used to apply the fertilizer. All plots received 60 kg P/ha broadcast as treble superphosphate before seeding grasses.

There was no irrigation before the first cutting. After the first cutting plots were flood irrigated. After the second harvest (about 20 August) a heavy irrigation was applied. A sickle-bar mower set at 2.5 cm was used to harvest 1.81 m² from each plot. Subsamples were taken for moisture determination and total N analysis by the Kjeldahl method.

RESULTS AND DISCUSSION

Forage Yields. Dry matter yields for canarygrass, foxtail, and brome, as affected by N fertilization, are shown in Table 1. First cutting forage yields generally increased as N applied increased up to 224 kg/ha. First cutting forage yields ranged from about 1,400 kg/ha for unfertilized canarygrass and brome to 7,460 kg/ha for the 448+448 kg N/ha treatment for the same grasses. First cutting yields from foxtail ranged from 1,698 to 6,373 kg/ha. The maximum yield from foxtail was about 1,000 kg/ha less than that from the other two species.

Second cutting forage yields ranged from 468 kg/ha for brome and 1,014 kg/ha for canarygrass with no fertilization to 3,810 kg/ha from the 224+224 kg N/ha treatment for brome. The 224+224 kg N/ha treatment also produced the highest second cutting yields for canarygrass; whereas, for foxtail, there was no significant difference between the 224+224, 448, or 448+448 kg N/ha treatments. Second cutting yields were higher for all grasses when the N application was split as compared with single spring treatments of the same total amount of N.

Table 2. Nitrogen content of three irrigated grasses as influenced by rate and frequency of N applied.†

Annual fertilizer treatment	Reed canarygrass		Garrison creeping foxtail		Smooth brome	
	Cutting		Cutting		Cutting	
	First	Second	First	Second	First	Second
kg/ha	%					
0	1.457^{cde*}	2.104^{abc}	0.893^{a}	1.567^{a}	1.430^{bcd}	1.959^{a}
56	1.204^{ab}	2.036^{ab}	0.776^{a}	1.584^{a}	1.185^{ab}	1.993^{a}
56+56	1.274^{abc}	2.191^{abcd}	0.775^{a}	1.706^{a}	1.064^{a}	2.339^{a}
112	1.141^{a}	2.015^{ab}	0.952^{a}	1.716^{a}	1.096^{a}	1.942^{a}
112+112	1.193^{a}	2.331^{bcd}	0.930^{a}	1.827^{a}	1.073^{a}	2.308^{a}
224	1.384^{bc}	1.896^{a}	1.294^{b}	1.871^{ab}	1.326^{abc}	2.138^{a}
224+224	1.464^{de}	2.555^{d}	1.357^{b}	2.456^{bc}	1.789^{e}	3.160^{b}
448	2.289^{f}	2.463^{cd}	2.029^{c}	1.967^{abc}	1.867^{e}	2.394^{a}
448+448	2.301^{f}	3.223^{e}	2.056^{c}	3.262^{d}	2.093^{e}	3.825^{c}

* Column means with similar superscripts are not significantly different at the 5% level. † Analysis based on 1969 and 1970 data for garrison creeping foxtail and smooth brome and on 1969, 1970, and 1971 data for reed canarygrass.

Total forage yields were 1,899, 2,351, and 2,430 kg/ha for brome, foxtail, and canarygrass, respectively, with no fertilizer applied. In general, total yields increased as fertilizer rate increased, to the 224+224 kg N/ha treatment, at which treatment yields were 8,135, 10,740, and 11,802 kg/ha for foxtail, canarygrass, and brome, respectively. There was no significant difference in total yield between the 224+224 and 448+448 kg N/ha treatments for any of the species. Brome was the most responsive and foxtail was the least responsive to N fertilization. Brome and canarygrass yields were increased about five-fold and the foxtail yield was increased about four-fold. There was no canarygrass or brome yield increase due to split fertilizer applications with less than 448 kg N/ha. Foxtail yields were always higher with single fertilizer applications but not significantly so.

N Content. First cutting forage N content from the 56, 56+56, 112, and 112+112 kg N/ha treatments did not differ significantly (Table 2). Unfertilized grasses often contained higher N contents than did forages fertilized at the low N rates. First cutting forage N content increased from a low 0.78% for foxtail at 56+56 kg N/ha to a high of 2.3% for canarygrass at 448+448 kg N/ha. Generally, for the first cutting, split application had little effect on N content.

Second cutting forage N contents were higher than those for first cutting for all species, varying from 1.57

Table 3. Nitrogen recovery of three irrigated grasses as influenced by rate and frequency of N applied.†

Annual fertilizer treatment	Reed canarygrass			Garrison creeping foxtail			Smooth brome		
	Cutting			Cutting			Cutting		
	First	Second	Total	First	Second	Total	First	Second	Total
kg/ha	N fertilizer recovered in forage, %								
56	20	1	21	15	4	19	14	1	15
56+56	13	9	22	8	8	16	14	22	36
112	31	1	32	28	6	34	19	6	25
112+112	17	11	28	14	10	24	17	20	37
224	34	2	36	26	9	35	21	8	29
224+224	19	15	34	14	12	26	25	27	52
448	30	7	37	23	9	32	19	12	31
448+448	17	8	25	11	9	20	13	17	30

† Analysis based on 1969 and 1970 data for garrison creeping foxtail and smooth brome and on 1969, 1970, and 1971 data for reed canarygrass.

to 3.83%. Second cutting N content did not differ significantly between single treatment applications except for canarygrass at the 448 kg N/ha rate. Generally, applying N fertilizer after the first cutting increased second cutting forage N content, indicating forage responded more from a split than from a single application.

Total N Recovery. Recovery of N in forage harvested from this experiment was calculated by subtracting total N uptake for unfertilized check plots from that of fertilized plots (assuming that N content in foxtail and brome in 1971 was the same as the average N content for 1969 and 1970). Table 3 shows that maximum first cutting recovery was 34% for the 224 kg N/ha treatment for canarygrass, 28% for the 112 kg N/ha treatment for foxtail, and 25% for the 224+224 kg N/ha treatment for brome. For a given rate of total N applied, recovery by first cutting was generally greater for single than for split applications.

Second cutting N recovery increased as N application increased to the 448 kg N/ha rate for single applications. Maximum N recovery was the 224+224 kg N/ha rate for split treatments. As expected, percent N recovery by the second cuttings was greater for split treatments. In all cases second cutting N recoveries from single applications were considerably lower than for first cuttings.

Average total N recovered in forage (first plus second cuttings) generally increased with N rate single applications to 224 or 448 kg N/ha rate. For split applications, percent recovery was greatest for the 224+224 kg N/ha treatment. For canarygrass and foxtail, N recovery was greater from single than from split applications, whereas the reverse was true for brome. Highest N recovery was 52% for brome fertilized at the 224+224 kg N/ha treatment. Much of this difference in species response was due to greater N recovery in second cutting brome from the split applications.

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